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CONTRACTOR REPORT ARLCD-CR-82062

INJECTION MOLDED PLASTIC OBTURATOR FOR 105-MM M735 PROJECTILE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of the contract was the development of a nonproprietary, low cost, production process for nylon obturators for the 105-mm M735 projectile that would give product performance equivalent to that obtained from current production machined from centrifugally cast nylon 6/6. Injection molding, using general purpose molding grade nylon 6/6 (DuPont Zytel 101L), was selected as the preferred process, based on cost analysis comparisons with compression and transfer molding. A single cavity, diaphragm-gate mold was designed and built.

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20. ABSTRACT (cont)

Molding cycles and post molding treatments were developed to minimize molded-in stress levels and to meet dimensional requirements after installation. Injection molded obturators met all the physical property requirements specified except for the water absorption value of 0.58 average vs maximum of 0.42. Installation on M735 projectiles was demonstrated successfully at ARRADCOM using modified standard procedures. Ballistic firing trials at -53°F, +70°F, and +145°F showed almost 1 to 1 correlation with control cast obturators.

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INTRODUCTION

This report summarizes the results of a program for the development of a non-proprietary process for the economic production of a plastic obturator for the 105-mm M735 projectile. The obturator is required to seal the high pressure propellant gases, and provide a controlled spin rate during gun firing. At the time of muzzle exit, the obturator must break reliably to permit sabot discard without interference with the projectile stabilizing fins. The obturator must function as described over the standard service temperature range of -40°F to +140°F.

Obturators that meet the above requirements have been made by machining centrifugally cast 6/6 nylon tubing to drawing dimensions. The process for the production of centrifugally cast tubing is proprietary and not available for general commercial use.

Based on a survey and cost analysis of possible non-proprietary methods, injection molding from 6/6 nylon was selected as the most promising for development although previous attempts had given erratic results.

The report will detail the tooling and process parameters developed for injection molding as well as a discussion of problems encountered, test results, and ballistic evaluation of the injection molded obturators furnished to the government.

TECHNICAL DISCUSSION

Background

The 105-mm APFSDS cartridge uses a nylon obturator to seal the high pressure (71,000 psi) propellant gases and provide a controlled spin rate during gun firing. To date, this obturator has been made from centrifugally cast nylon 6/6 manufactured by one supplier using a proprietary process. This report covers a program to select an alternate production process and material, and to demonstrate that obturators made by this process and material can be assembled to M735 projectile within drawing requirements, and perform satisfactorily under gun fire conditions.

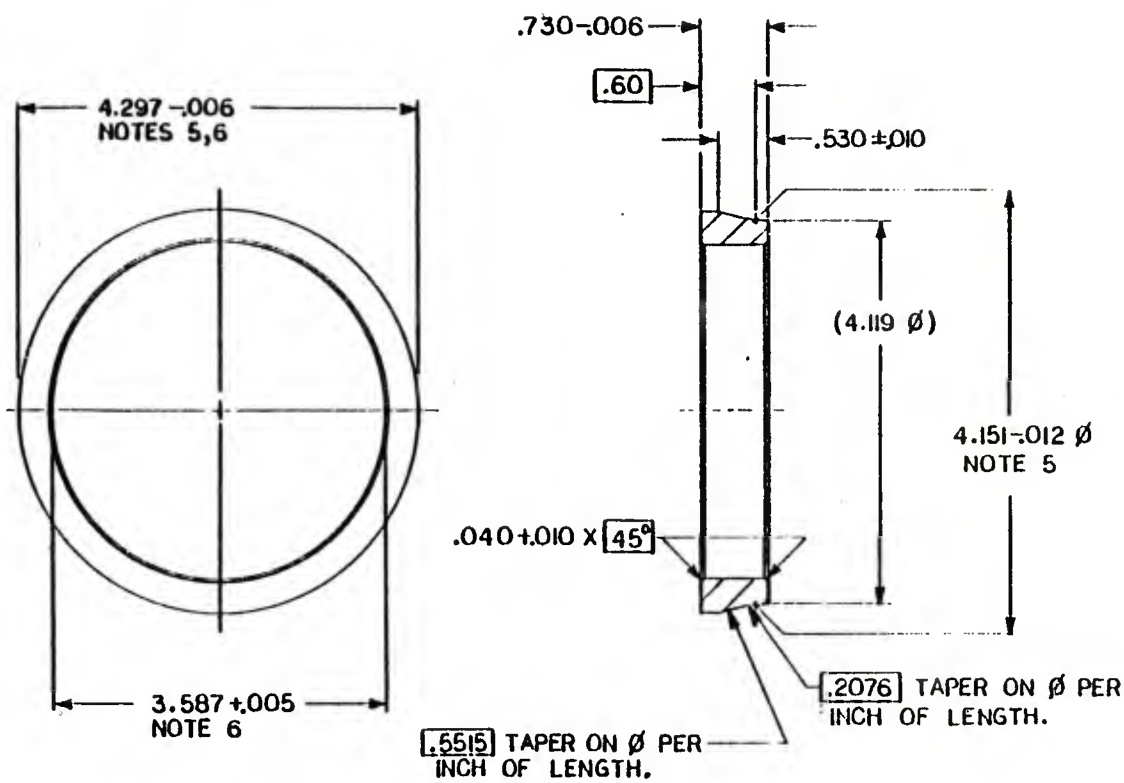
Drawing PA-C14-B Figure 1, Page 3 (based on ARRADCOM Dwg. VFM2083 Rev. A) gives the target dimensions and physical properties for the program. Since the listed physical properties were based on those determined for cast nylon, some variations were anticipated, with the hope that ballistic requirements would still be met. In addition, the inside and outside diameters were advisory as long as final assembly dimensions were met. The material specified was a commercially available nylon 6/6 meeting the requirements of MIL-M-20693B, composition A Type I.

Process Selection

The requirements evaluated during the selection of an alternate production process were as follows:

1. non-proprietary
2. commercially available
3. ability to produce an acceptable product
4. ability to meet production rates of 20,000 units per month
5. economical

Using these requirements, the three most common processes for producing close tolerance parts from thermoplastic raw materials were studied. These are compression molding, transfer molding, and injection molding. In each process, raw material (thermoplastic molding compound) is heated above its melting point and forced to conform to the geometry of a mold cavity by the application of pressure. The cavity duplicates the geometry of the finished part with a calculated shrinkage allowance applied to all dimensions. The hot plastic is then solidified by cooling to below its melting point in the cavity under pressure, prior to removal as a molded part.



Notes:

1 - Spec MIL-A-2550 and ANSI Y14.5--1973 apply.

2 - Material : Zytel 101, Composition A, Type 1, MIL-M-20693.

3 - Physical Properties of Obturator:

A - Min. load to break lbs.

$-35^{\circ}F \pm 3^{\circ}F$	4400
$73^{\circ}F \pm 8^{\circ}F$	3500
$140^{\circ}F \pm 3^{\circ}F$	2400

B - Extension, Inches Min.

$-35^{\circ}F \pm 3^{\circ}F$	0.2
$73^{\circ}F \pm 8^{\circ}F$	0.70
$140^{\circ}F \pm 3^{\circ}F$	1.25

C - Water Absorption, % Max. 0.42

D - Moisture Content, % Max. 0.20

E - Specific Gravity

Min.	1.13
Max.	1.16

F - Rockwell Hardness R Scale

Min.	110

4 - Finish 125√ all surfaces.

5 - Maximum wall variation when measured from 3.587 + .0050 to diameters indicated shall not exceed 0.005 inch rfs.

6 - These dimensions are advisory as long as final assembly dimensions of DWG 9328524 are met.

REF: ARRADCOM DWG VFM2083 REV. A

Figure 1. Obturator

In Compression Molding, a weighed quantity of raw material slightly higher than final part weight is placed in the cavity with the mold open. As the mold is closed, the material is compressed in the cavity with the excess squeezed out as "flash" at the cavity parting line. Material can be heated prior to molding either by auxiliary means (oven, dielectric, etc.) outside the mold, or by contact with the surface of a heated mold. If the mold temperature is above the melting point, it must be cooled sufficiently to permit part removal and then reheated for the next shot.

In Transfer Molding, this same weighed and preheated quantity of material is placed in a separate cavity (transfer pot) from which it is forced by a moving piston (plunger) through a channel (runner) into the cavity with the mold closed. Any excess material remaining in the pot is discarded - or recycled. Transfer molding eliminates the flashing of excess material, with its potential appearance and dimensional problems, as well as providing excess material in the pot that can be forced into the cavity during cooling to compensate for shrinkage. Mold temperature cycling is similar to that required for compression molding.

In Injection Molding, a quantity of material in excess of part weight is continually maintained at molding temperature. Material from this reservoir (injection cylinder) is forced under high pressure by a hydraulic ram (piston), or feed screw acting as a ram, into the cavity with the mold closed. The mold is maintained at a temperature below the melting point, allowing part removal without temperature cycling. Since fresh material is added to the reservoir and heated during each cycle, the process is essentially continuous with cycle times determined primarily by the time required to cool the part in the mold. Tooling is usually more expensive than that required for compression or transfer since the pressures involved are higher. In addition, the molding machine itself is more complex and expensive. These added costs are balanced by a higher production rate, and closer control of process variables.

Cost summaries in 1981 dollars for the three processes are given in Tables 1, 2, and 3 on pages 5, 6, and 7. This analysis, plus the close control of part quality through control of process variables, dictates the selection of injection molding as the preferred process.

Table 1. Cost estimate - injection molded obturators with 24,225 pieces per month

	Dollars Per Month	Dollars Per Obturator
Operating Costs		
Variable		
Raw material	11,125	0.4592
Direct labor	11,025	0.4551
Fringes on DL, 30%	3,308	0.1366
Utilities	1,308	0.0540
Freight in and out	---	---
Packaging	727	0.0300
Maint. supplies	238	0.0098
Maint. labor	238	0.0098
Other supplies	223	0.0092
By products credits	---	---
	28,192	1.1637
Fixed		
Indirect labor, 0.8 DL	8,820	0.3641
Fringes on IL, 30%	2,646	0.1092
Depreciation	2,881	0.1189
Insurance and taxes	358	0.0148
Maint. supplies	119	0.0049
Maint. labor	119	0.0049
Space charge	750	0.0310
	15,693	0.6478
Manufacturing Cost	43,885	1.8115

- -

Capital equipment	143,000	
Working capital 1.5 x 43,885	65,828	
Total capital employed	208,828	
ROI at 20%	$41,766/yr or	$0.1437 per obturator
Manufacturing cost		1.8115
ROI plus manufacturing cost		$1.9552 per obturator

Table 2. Cost estimate - transfer molded obturators with 24,225 PCS per month pieces per month

	Dollars Per Month	Dollars Per Obturator
Operating Costs		
Variable		
Raw material	11,016	0.4547
Direct labor	11,025	0.4551
Fringes on DL, 30%	3,308	0.1366
Utilities	2,467	0.0606
Freight in and out	---	---
Packaging	727	0.0300
Maint. supplies	292	0.0121
Maint. labor	292	0.121
Other supplies	221	0.0091
By products credits	---	---
	28,348	1.1702
Fixed		
Indirect labor, 0.8 DL	8,820	0.3641
Fringes on IL, 30%	2,646	0.1092
Depreciation	3,753	0.1549
Insurance and taxes	438	0.0181
Maint. supplies	146	0.0060
Maint. labor	146	0.0060
Space charge	750	0.0310
	16,699	0.6893
Manufacturing cost	45,047	1.8595

- -

Capital equipment	175,000	
Working capital 1.5 x 45,047	67,571	
Total capital employed	242,571	
ROI at 20%	$ 48,514/yr or	$0.1669 per obturator
Manufacturing cost		1.8595
ROI plus manufacturing cost		$2.0264 per obturator

Table 3. Cost estimate - compression molded obturators with 21,533 PCS per month pieces per month

	Dollars Per Month	Dollars Per Obturator
Operating Costs		
Variable		
Raw material	9,792	0.4547
Direct labor	11,025	0.5120
Fringes on DL, 30%	3,308	0.1536
Utilities	1,257	0.0584
Freight in and out	---	---
Packaging	646	0.0300
Maint. supplies	265	0.0123
Maint. labor	265	0.0123
Other supplies	196	0.0091
By products credits	---	---
	26,754	1.2425
Fixed		
Indirect labor, 0.8 DL	8,820	0.4096
Fringes on IL, 30%	2,646	0.1229
Depreciation	3,371	0.1566
Insurance and taxes	398	0.0185
Maint. supplies	133	0.0062
Maint. labor	133	0.0062
Space charge	750	0.0348
	16,251	0.7547
Manufacturing cost	43,005	1.9972

Capital equipment	159,000	
Working capital 1.5 x 43,005	64,508	
Total capital employed	223,508	
ROI at 20%	$ 44,702/yr or	$0.1730 per obturator
Manufacturing cost		1.9972
ROI plus manufacturing cost		$2.1702 per obturator

Material

The material in current use for the VFM2083 M735 obturator is described as centrifugally cast nylon 6/6. The material selected for injection molding evaluation was Zytel 101 - a general purpose injection molding grade of nylon 6/6 from E. I. DuPont. Certification and test data of this product are given in Appendix A, page 35. The grade actually used in production was 101L - internally lubricated for improved feed and mold release characteristics. In addition to 101L, two grades of Allied Chemical Type 6 nylons, Capron 8202 and 8253 copolymer, were molded for evaluation but were eliminated from further consideration based on initial test results as reported in Table 4, page 9.

The target physical properties based on cast nylon are given in drawing PA-C14-B, page 3. Obturators molded from Zytel 101L met these target requirements with the exception of water absorption. There appears to be, however, differences between cast 6/6 nylon and molded 101L that may be significant after long term storage over the range of temperature and humidity to be encountered in the field. These differences lie in the areas of rate of moisture pick-up and change in physical properties with moisture content.

A comparative analysis for the crystalline melting point by Differential Thermal Analysis gives 259°C (498.2°F) as the melting point for the cast nylon and 266°C (510.8°F) for molded Zytel 101L. The lower melting point and wider peak, Ref. Figures 2, and 3 pages 10 and 11 would suggest the presence of a material modification, or modifier, that could explain the differences in physical property changes with moisture.

In an attempt to measure the change in physical properties with moisture, two cast nylon obturators were conditioned as shown in schedule A, page 12, while two molded obturators were conditioned per schedule B, page 12. During the conditioning process it became apparent that the cast and molded nylons were picking up moisture at very different rates, Ref. Figure 4, page 13. As a result of this, it was necessary to dry the molded obturators to reach the 2.5% target moisture content - long term storage at 50% RH, while cast obturators never reached 2.5% and were tested at 1.67%. One of the molded obturators was oven annealed at 250°F for 60 minutes to determine residual stress after conditioning. The resulting changes in dimension and physical properties are given in Tables 5 and 6, page 14. Although the moisture levels tested were not the same, the changes in load and elongation would appear to be significantly greater for the molded Zytel 101L. Dimensional changes are as expected: the cast nylon can only grow with moisture since it starts dry/annealed while the molded parts show the combined effects of stress relief and moisture pickup.

Table 4. Initial physical property evaluation*

Obturator Type	Load @ Yield lbs	Load @ Break lbs	Extension @ Break in	Hardness Rockwell R	Specific Gravity
Cast Nylon Controls					
C1	6020	5460	1.118	110	1.157
C2	5860	4815	1.049	110	1.157
Allied 6 (8202)					
4		3002	0.146	108	1.137
7		3982	0.198	108	1.137
Allied 6 (8253)					
4	3248	2261	1.315	99	1.097
7	3179	2750	3.177	99	1.098
DuPont 66 (101 L)					
14	5070	4210	0.733	111	1.144
19	4966	3908	0.832	111	1.144
25	5014	4251	0.844	111	1.145
27	5057	4211	0.738	111	1.145
38	5037	4094	0.764	111	1.144
42	4975	3990	0.757	111	1.144
Specifications per Drawing VFM 2083 (min values)	----	3500	0.70	110	1.13 1.16 Max

* Tensile elongation @ 73°F per QEP-TR-316; hardness; specific gravity.

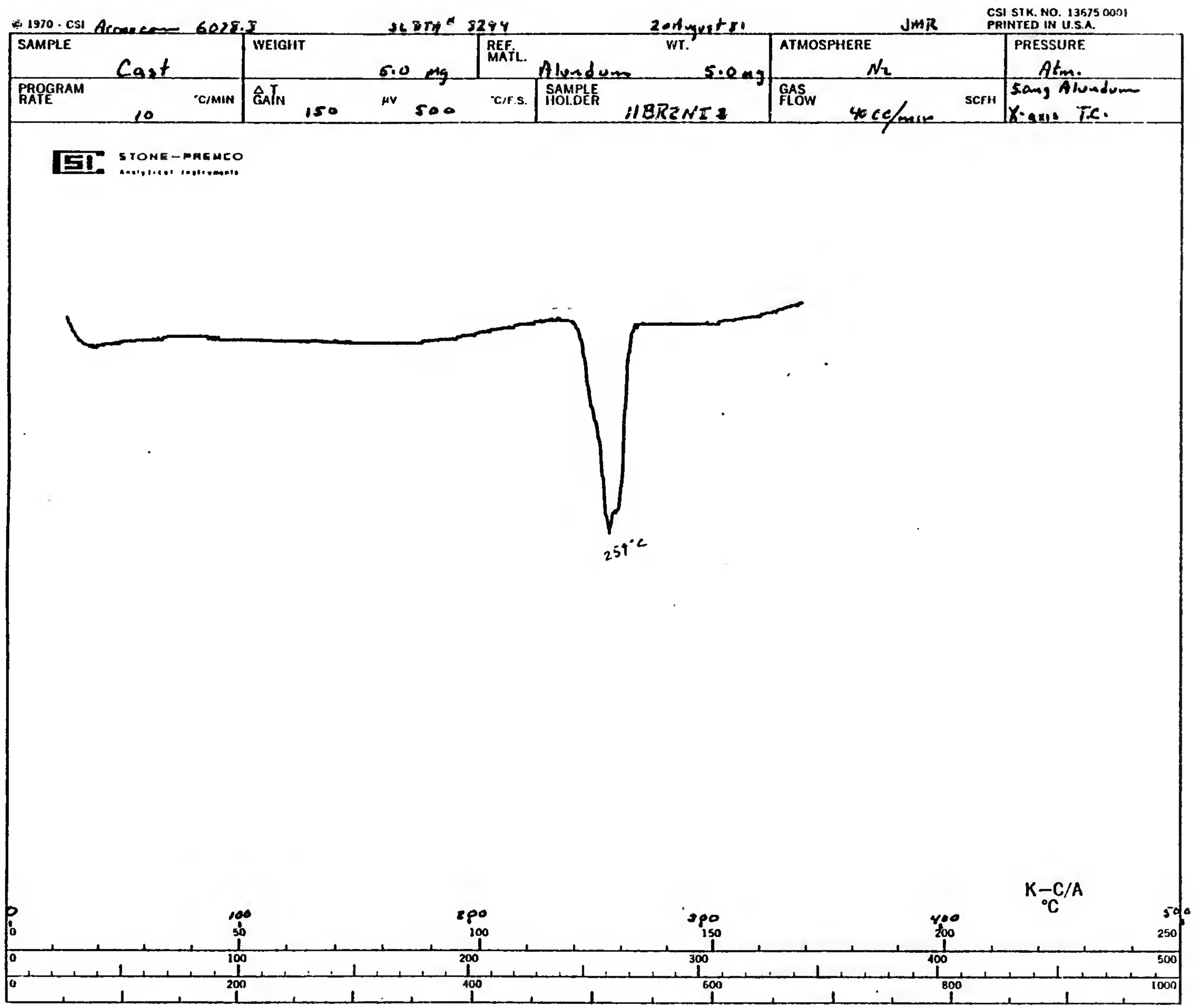


Figure 2. Melting point by differential thermal analysis (DTA) cast nylon

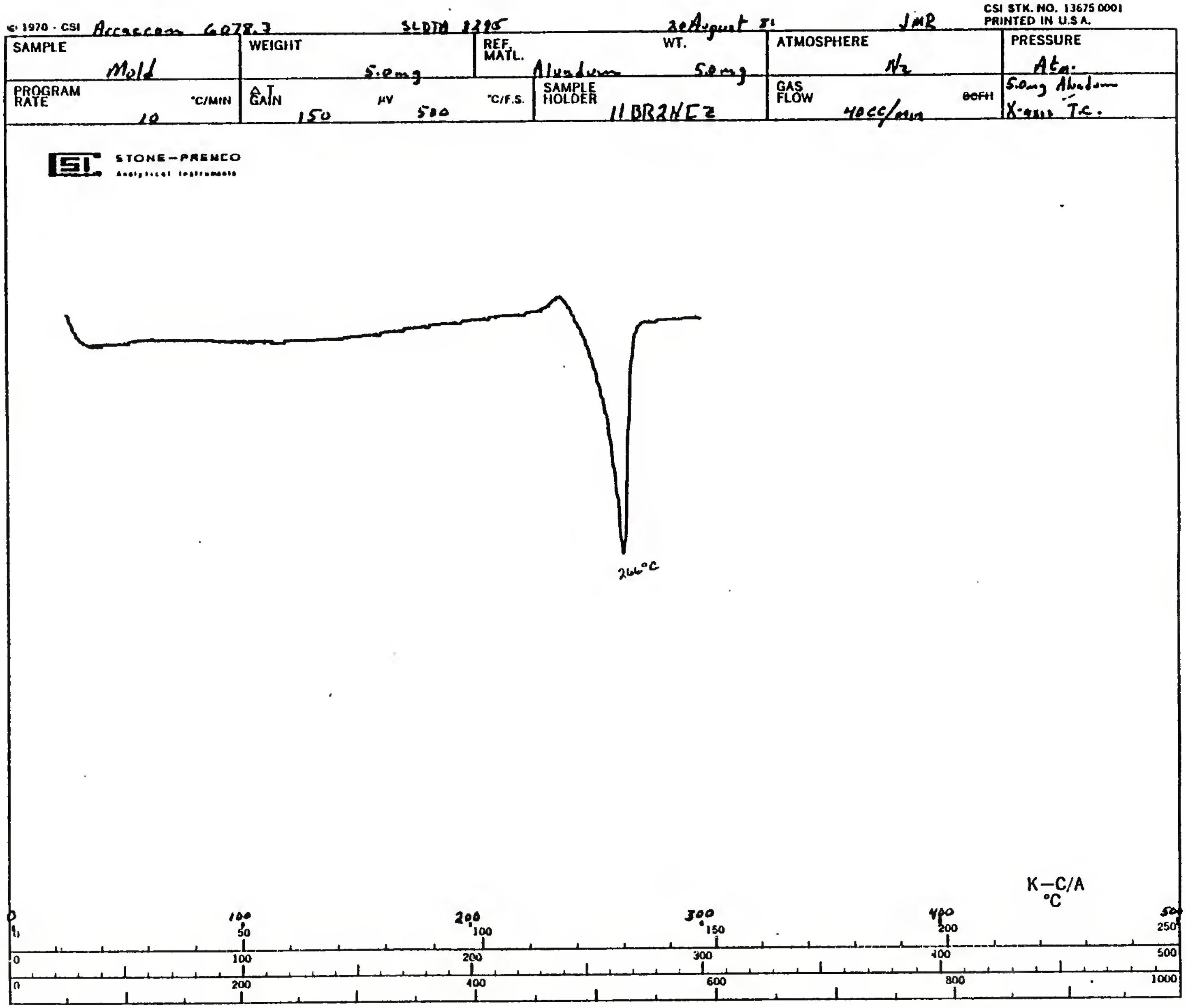


Figure 3. Melting point by differential thermal analysis (DTA) molded nylon

Schedule A

Cast:	% H_2O As Received	
8 hrs 170°F oven + 16 hrs dessicator	Assume 0	
8 hrs 210°F water + 16 hrs Al foil wrap	1.10%	
72 hrs foil wrap	.97%	
16 hrs (total) 210°F water + 16 hrs Al foil wrap	1.58%	
24 hrs (total) 210°F water + 16 hrs Al foil wrap	1.84%	
96 hrs room t & H	1.67%	T

Schedule B

Molded:		% H_2O As Molded	
		Assume 0	
4 hrs 210°F water		1.60%	
21 hrs (total) 210° water		3.65%	
25 hrs (total) 210°F water		3.87%	
96 hrs room t & H		3.49%	
8 hrs 170° oven + 16 hrs dessicator		2.81%	
8 hrs 170° oven + 16 hrs dessicator		2.56%	
8 hrs 170° oven + 16 hrs dessicator		2.25%	T
96 hrs room t & H	D-1	2.41%	T
1 hr 250°F oven	D-12	2.03%	T

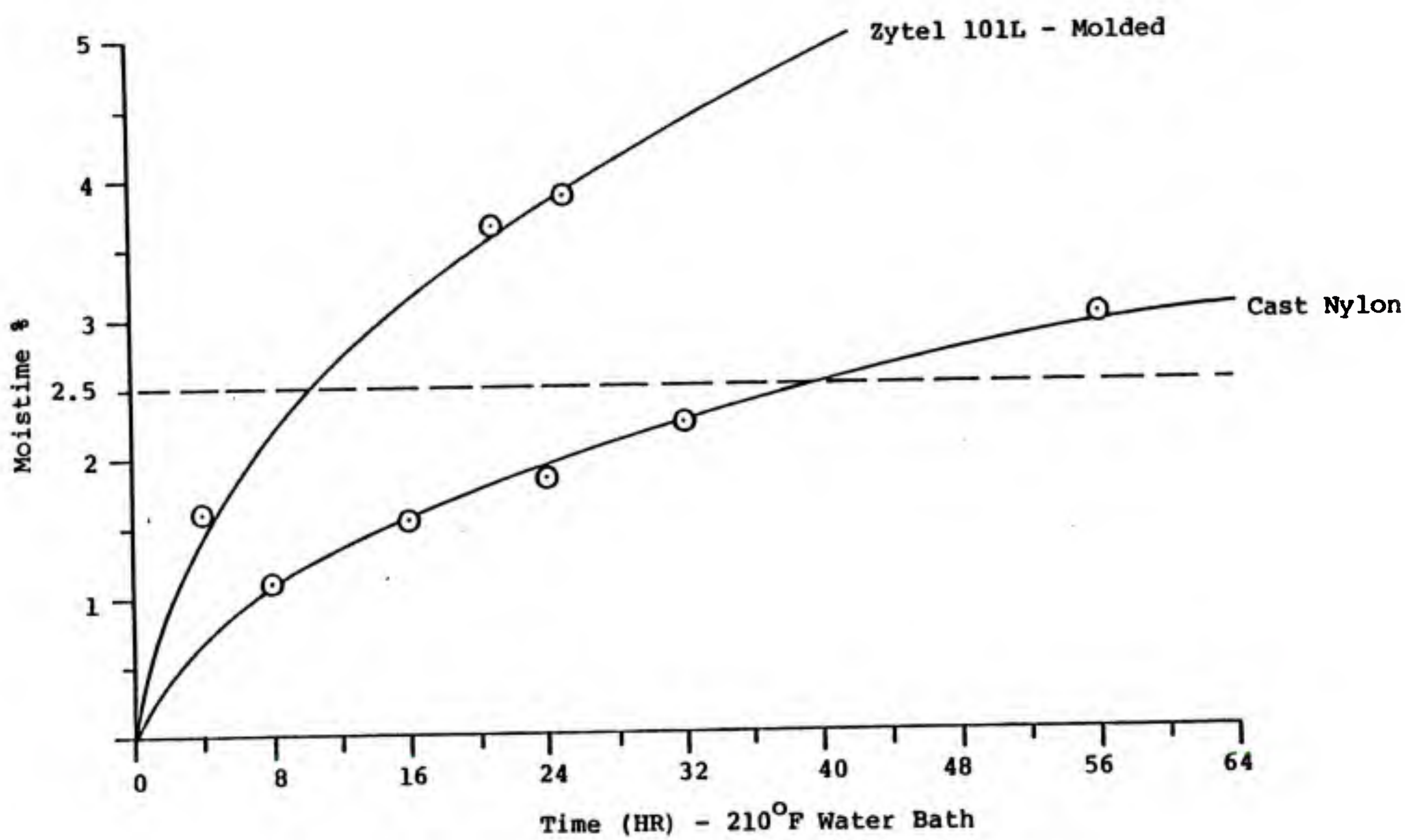


Figure 4. Water absorption versus time

Table 5. Change in OD with water absorption

Sample	Initial OD	% H_2O	Final OD	% Change
Cast 1	4.297	1.67	4.313	+ 3.7
Cast 2	4.297	1.67	4.315	+ 4.2
D-1 (6/5/81)[1]	4.301	2.03	4.283	- 4.2
D-12 (6/5/81)	4.299	2.41	4.299	0

Table 6. Change in physical properties with water absorption tensile elongation at 73°F per QEP-TR-316

Sample	% H_2O	Peak Load (lbs.)	Break Load (lbs.)	Extension (inches)
Cast Control	As Rec'd	5860	4815	1.05
Cast 1	1.67	4840	3870	1.474
Cast 2	1.67	4870	4080	1.371
D-8 Control	As Molded	5200	4050	.810
D-1*	2.03	3706	2770	4.736
D-12	2.41	3600	2920	4.738

* Sample D-1 oven annealed at 250°F for 60 minutes after conditioning to 2.30% H_2O.

Tooling

Based on the selection of injection molding, a single cavity tool was designed and built per Figure 5 and Appendix B. Axial flow with a diaphragm type gate was used to eliminate the possibility of knit lines in the molded part, although the diaphragm gate required a machining operation for removal and a 55 percent scrap factor. The scrap factor could be reduced in production tooling by the use of a hot sprue bushing, and the use of a percentage of regrind rather than 100 percent virgin material.

The mold was cored to permit individual temperature control for both the cavity and core inserts with circulating water. At mold open, the part was retained on the core by shrinkage and ejected by a ring knockout. The center sprue puller pin was not required, and was replaced with a flush pin during the experimental runs. A single .187 dia knockout pin was used with the ring knockout to activate a pressure transducer and permit a recording of cavity pressure vs. time using a Control Process Model 221 pressure recorder.

The initial design used a core with a .015 inch/inch shrinkage allowance and a cavity with a .010 inch/inch allowance. These were changed to .0206 and .0199 respectively based on measurements of molded parts. These dimensions gave molded obturators within drawing dimensions prior to annealing. The final measured shrinkage after a 60 minute air oven anneal at 250°F was .022 inch/inch based on OD measurements. The tooling was not corrected to this value since installation on projectiles to specification requirements had been demonstrated. It is also probable that dry annealed parts will increase in size with moisture pickup and approach the original as molded dimensions. The runner system started with a standard sprue bushing - minimum ID 9/32 (.281) feeding a .260 thick diaphragm. The gate into the thin end of the obturator was .175 in cross section - 65 percent of part thickness - enlarged from the original design value of .118 to eliminate the possibility of material freeze.

The mold as designed, and modified for dimension, worked satisfactorily except for a wall thickness (concentricity) problem that developed during use. This was caused by a combination of cavity insert fit and guide pin wear, resulting in a .004 core vs. cavity centerline shift and giving wall thickness variations of .008. The problem was corrected by installing tapered interlocks on the mold parting line with the core and cavity centered, and holding the cavity insert in the correct location with a set screw.

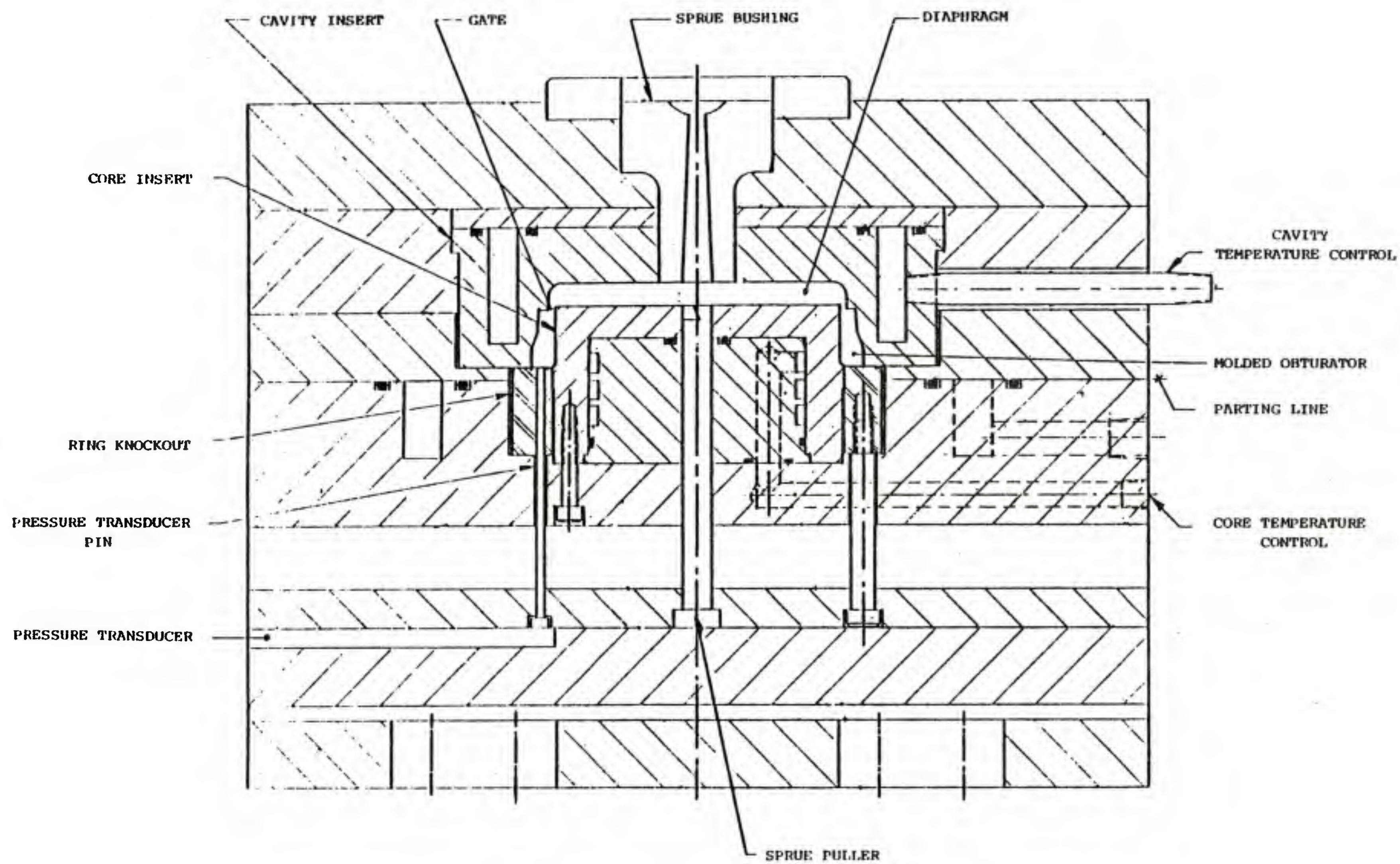


Figure 5. Single cavity injection mold for VFM2083 revision A obturator

Injection Molding

Initial Molding Trial

Initial mold tryout was done on a Buhler 175 Ton toggle clamp injection molding machine fitted with a 6 oz. reciprocating screw injecion unit - 45 mm dia. screw, 2.9:1 compression ratio, 18:1 L/D, with a ring type non-return valve. Mold temperature control was provided by a two zone Supertrol controlled temperature circulating water system. The mold was sampled with Zytel 101L and two grades of Allied Corp. Nylon 6, Capron 8202 and 8253 copolymer. The results of physical property tests per QEP-TR-316 are shown in Table 4 page 18, and molding cycle parameters are detailed in the Appendix, Section C, page 43. Molded parts were measured, and the cavity and core recut to permit molding to drawing requirements. Based on the results obtained, no problems in meeting physical property requirements with Zytel 101L were anticipated. There were, however, problems with raw material feed and control of molding process parameters with the Buhler machine, and all other molding runs were made on a Beloit Model 325 RS full hydraulic injection molding machine fitted with a 6 oz. reciprocating screw injection unit - 1 3/4 dia. screw, 3.5:1 compression ratio, 16:1 L/D with a ring type non-return valve. The same mold temperature control unit was used, and cavity pressure was recorded for each molding cycle on a Control Process Model 220 pressure recorder using a DME Model 405C transducer activated by a 3/16 dia. pin.

A molding run was made on 6/5/82 to evaluate variations in mold temperature, injection pressure, and injection time. Molding cycle parameters are detailed in Appendix Section C, page 44 and the results of tensile elongation testing and dimensional measurements are given in Tables 7 and 8, page 18. Based on these results, cycle C was selected as giving the best combination of physical properties and dimensions in the "as molded" condition.

Quality Evaluation Trial

A quantity of 153 obturators was molded on 6/23/81 to give the initial quality evaluation sample per 4.3.1 of QEP-TR-316. Molding resin used in the run was dried at 170°F for an average of 18 hrs. using dehumidified air in a circulating air oven. Rings, as molded, were cooled on a sheet metal table top and stabilized for 24 hrs. before machining for gate removal and chamfer. Average OD prior to annealing was 4.304 with a ± .002 variation. Rings were partially annealed (30 minutes - 200°F air circulating oven) to bring the average OD to 4.295 ± .002. Ref: Dwg. specification of 4.297 - .006.

Table 7. Average outside diameters at thick end cycles B, C, D, and E - molding run of 6/5/81

Cycle (quantity)	Average OD	Standard Deviation
B (7)	4.2823	.0015
C (11)	4.2945	.0010
D (10)	4.2947	.0013
E (10)	4.2875	.0027
Target Specification	4.297 - .006	

Table 8. Tensile elongation at 73°F per QEP-TR-316 cycles B, C, D, and E - molding run of 6/5/81

Sample No.	Peak Load (lbs.)	Break Load (lbs.)	Elongation (inches)
B 3	5100	3780	.893
B 7	5100	4200	.783
C 1	5170	4220	.853
C 4	5200	4100	.794
C 9	4650	3950	.823
D 3	5200	3970	.823
D 8	5200	4050	.810
D 11	5180	4010	.872
E 5	5220	4170	.911
E 9	5230	4170	.869
E 12	4340	4340	.230
Target Specification	3500 Minimum		.7 Minimum

The annealed rings were stored at room temperature and humidity for approximately two weeks before a minimum 72 hrs. at 73°F and 50% RH conditioning and the start of Government witnessed testing on 7/20/81. Molding cycle data is given in the Appendix Section C, page 45. Test results per QEP-TR-316 are reported in Table 9, pages 20 and 21.

The major problem in test results was in the lack of uniformity of the 73°F tensile-elongation data. All rings tested passed the 3500 pound minimum strength to break, but elongations at break varied from .173 to .915 (average .62) under a .70 minimum specification.

One ring broke short (1.055) at 140°F but all other values except moisture content at .3% and water absorption at .65% were within specification values.

This lack of uniformity - brittle fracture - could be caused by voids, inclusions, or high (uneven) molded in stress. X-ray and visual inspection of samples that broke short (No's 5 and 9) showed no voids or inclusions leaving stress as the probable cause. Possible sources of such stress levels were as follows:

1. Molding resin too dry - optimum moisture content appears to be .15 to .35%.

2. Stress caused by uneven or too rapid cooling.

3. Stress caused by the high injection pressures used to eliminate voids and meet dwg. tolerance.

4. Stress that could be removed by annealing after molding.

Process Development

To evaluate these factors, a molding run was made on 8/13/81 to determine the lowest pressure that would result in void-free parts. Molding conditions except for pressure were held constant and are detailed in Appendix Section C, page 46. Cavity pressure curves for 6000 psi (6K), 8000 psi (8K), and 10,000 psi (10K) are given in the Appendix Section D, page 53. The molding resin was Zytel 101L, Lot 63FN4, with a moisture content of 0.18% - used from a new bag and stored in glass jars under a N_2 purge.

Three samples from each condition were x-ray inspected for voids. None were found in the 6K and 10K series, but two out of three 8K samples had voids. Based on this, the 6000 psi cycle was selected as the least likely to give molded in-stress problems.

Table 9. Physical property testing per QEP-TR-316 quality evaluation sample - molding run of 6/23/82

A. Tensile Elongation at $-35^{\circ}F$ Method 4.5.1

Samples (No. Tested)	Peak Load (lbs.)	Break Load (lbs.)	Elongation (inches)
Average (12)	7064	6894	0.512
High	7580	7580	0.787
Low	6350	6350	0.322
Std. Deviation	462	381	0.187
Target Specification - minimum	4400 lbs.		0.2 inches

B. Tensile Elongation at $73^{\circ}F$ Method 4.5.1

Samples (No. Tested)	Peak Load (lbs.)	Break Load (lbs.)	Elongation (inches)
Average (12)	4838	4518	0.617
High	5100	5040	0.915
Low	3640	3640	0.173
Std. Deviation	461	442	0.271
Target Specification - minimum	3500 lbs.		0.7 inches

C. Tensile Elongation at $+140^{\circ}F$ Method 4.5.1

Samples (No. Tested)	Peak Load (lbs.)	Break Load (lbs.)	Elongation (inches)
Average (12)	3534	No Break	No Break
High	3598	N/A	N/A
Low	3450	2790	1.055 (1)
Std. Deviation	43	N/A	N/A
Target Specification - minimum	2400 lbs.		1.25 inches

Table 9. (cont)

D.	Rockwell Hardness R Scale	Method 4.5.2	
	6 Samples - 4 Readings Each		
	Average (24 readings)	110	
	High	113	
	Low	108	
	Std. Deviation	1.6	
	Target Specification - minimum	110	
E.	Specific Gravity	Method 4.5.3	
	6 Samples - 2 Readings Each		
	Average (12 readings)	1.144	
	High	1.146	
	Low	1.142	
	Std. Deviation	0.0013	
	Target Specification - minimum	1.13	maximum 1.16
F.	Moisture Content - Percent	Method 4.5.4	
	Average Value (10 Samples)	0.304	
	High	0.32	
	Low	0.29	
	Std. Deviation	0.011	
	Target Specification - maximum	0.20	
G.	Water Absorption - Percent		
	Average Value (10 Samples)	0.646	
	High	0.66	
	Low	0.64	
	Std. Deviation	0.007	
	Target Specification - maximum	0.42	

Using the 6000 psi cavity pressure cycle, a second molding run was made on 8/14/81 and 8/17/81 to evaluate the effect of post molding treatments. Molding cycle data is given in the Appendix Section C, page 47 and cavity pressure curves in the Appendix Section D, page 54. Molded obturators were treated as follows:

1 thru 12	Cooled in free air on a steel table top.
13 thru 24	Removed from the mold and immediately placed in cardboard boxes (single wall 175 lb. test 4 to a box) in a 250°F air circulating oven for 60 minutes. After removal from the oven, the boxed parts were cooled for 48 hours before gate removal.
25 thru 36	Removed from the mold and immediately placed in cardboard boxes and allowed to cool for 48 hours. The parts, still boxed, were then annealed for 60 minutes in a 250°F air circulating oven and cooled in the boxes for 24 hours before gate removal.
37 thru 48	Removed from the mold and immediately placed in cardboard boxes and allowed to cool for 48 hours before gate removal.

In a continuation of the run, the mold temperature was raised to 195°F. All other parameters were held constant and parts were molded and treated as follows:

49 thru 58	Removed from the mold and immediately placed in cardboard boxes and allowed to cool for 48 hours before gate removal.
59 thru 68	Removed from the mold and immediately placed in cardboard boxes and allowed to cool for 48 hours. The parts, still boxed, were then annealed for 60 minutes in a 250°F air circulating oven and cooled in the boxes for 24 hours before gate removal.

All parts were measured for outside diameter and conditioned at 73°F and 50% RH for a minimum of 72 hours before ring tensile testing at 73°F. Two parts were x-rayed from each series as well as those that failed tensile elongation. Dimensional and Tensile elongation data is given in Tables 10, 11, and 12 on pages 23 and 24.

Table 10. Average outside diameter - as molded versus as treated molding cycle of 8/14/81

Series Identification	As Molded	As Treated	$\triangle$
1-12 (5)	4.299	N/A	N/A
13-24 (10)	N/A	4.282	N/A
25-36 (10)	4.295	4.281	.014
37-48 (5)	4.295	N/A	N/A
49-58 (5)	4.286	N/A	N/A
59-68 (5)	4.286	4.281	.005

Table 11. Tensile elongation at 73°F per QEP-TR-316 defect free parts - visual and x-ray injection molding cycle of 8/14/81

Series Identification	Peak Load (lbs.)	Break Load (lbs.)	Elongation (inches)
1-12 (4) Average	5128	4067	0.684
Std. Deviation	31	125	0.029
13-24 (8) Average	5214	4408	0.771
Std. Deviation	42	116	0.046
25-36 (7) Average	5238	4264	0.832
Std. Deviation	20	113	0.035
37-48 (3) Average	5165	4019	0.764
Std. Deviation	17	225	0.124
49-58 (3) Average	5238	4212	0.730
Std. Deviation	12	178	0.050
59-68 (3) Average	5319	4475	0.710
Std. Deviation	40	274	0.019

Table 12. Average elongation at 73°F per QEP-TR-316 parts with defects - voids or inclusions

Series (# Defective)	Voids	Inclusions	Elongation	Deviation
1-12 (1 of 5)	0	1	0.180	N/A
13-24 (2 of 10)	1	1	0.350	0.14
25-36 (3 of 10)	0	3	0.174	0.07
37-48 (2 of 5)	1	1	0.242	0.11
49-58 (2 of 5)	2	0	0.370	0.06
59-68 (2 of 5)	2	0	0.434	0.00

Comments:

1. Parts molded at 195°F cavity temperature had more voids than those molded at 150°F - 4 out of 5 x-rayed vs. 2 out of 13. Differences observed at these conditions between annealed and as molded rings in tensile elongation values can be explained by moisture content.

2. Parts with defects - either voids or foreign material (inclusions) give a one for one correlation with brittle failure in ring tensile testing.

3. Annealing - even the annealing achieved by slower cooling in cardboard improves elongation. The average elongation for each series is as follows:

1-12	0.684
13-24	0.771
25-36	0.832
37-48	0.764
49-58	0.730
59-68	0.710

4. Annealing at 250°F improves elongation, and a two-step process (25-36) gave better results than a one-step process (13-24).

5. Based on results to date, the treatment used for the (25-36) series would give acceptable molded obturators, if voids and/or inclusions can be eliminated.

Preliminary Firing Trial

To confirm the above results a molding run was made on 9/17/81 using 6000 psi cavity pressure with variations in the mold temperature profile intended to eliminate voids. All other cycle and post mold treatment parameters were held constant, except for the use of a different lot of Zytel 101L. As before, molded parts were cooled in cardboard boxes (4 to a box) for 48 hours minimum, annealed in the boxes for 1 hour at 250°F in a hot air oven, and allowed to cool for 24 hours before machining for gate removal.

Parts from each series were x-ray inspected for voids and visually inspected for inclusions prior to tensile/elongation testing at 73°F after 72 hours minimum conditioning at 73°F and 50% RH. Molding cycle data sheets are given in the Appendix, Section C, page 48 and test results are given in Tables 13 and 14 on page 26.

No voids were found in the parts x-rayed from cycles A and B. One void was found out of the 11 parts x-rayed from cycle C, and 2 out of the 5 parts x-rayed from cycle D. Cooling the cavity - even from one side only - appears to cause premature gate freeze and, therefore, a higher incidence of voids.

All parts tested for tensile/elongation gave acceptable results with cycle C giving the highest uniformity.

A quantity of 5 obturators selected from cycles A, B, and C after x-ray and visual inspection were assembled to projectiles at ARRADCOM and test fired at Camp Edwards on 11/13-14/81. All 5 met the pressure and velocity requirements with two of the five showing a slight, but acceptable, degree of yaw. Firing was done at service charge using a constant twist, .009 worn tube on projectiles conditioned to 142°F for 24 hours minimum.

Final Molding Cycle

Based on the success of the firing trials, a "final" molding run using cycle was made on 1/18/82. During final machining and inspection of the 225 parts produced, the wall thickness (concentricity) problem discussed in the section on Tooling was discovered. Following mold rework, a final molding run of 330 pieces was made on February 16th and 17th. A molding cycle data sheet and cavity pressure curve for this run are given in the Appendix Section C, page 49 and Section D, page 54. Slow cool and annealing procedures were identical to those used for the run of 9/17/81. Following gate removal/machine to length and a chamfering cut on the ID, the parts were inspected for dimension and workmanship, and a quantity of 300 selected for shipment as Item 0001 on Mod P00004 as given in Appendix E, page 60.

Table 13. Average outside diameter - as molded versus as treated cycles A, B, C, and D - molding run of 9/17/81

	Series	As Molded	As Treated	$\triangle$
A	(12)	4.2957	4.2838	.0119
	Std. Deviation	.0008	.0006	
B	(12)	4.2963	4.2843	.0120
	Std. Deviation	.0016	.0010	
C	(16)	4.3044	4.2872	.0172
	Std. Deviation	.0006	.0008	
D	(12)	4.3099	4.2868	.0231
		.0008	.0011	

Table 14. Tensile elongation at 73°F per QEP-TR-316 cycles A, B, C, and D - molding run of 9/17/81

	Series	Peak Load (lbs.)	Break Load (lbs.)	Elongation (inches)
A	(3) Average	5222	4294	0.7626
	Std. Deviation	25	66	.066
B	(3) Average	5246	4242	0.7699
	Std. Deviation	13	150	.068
C	(3) Average	5261	4211	0.7667
	Std. Deviation	2	104	.007
D	(3) Average	5199	4119	0.7429
	Std. Deviation	24	119	.040

Dimensional inspection, as reported, showed part-to-part variation within ± .002, with the average diameter values smaller than drawing by about .010. As discussed previously, the .010 undersize condition is the result of the annealing step after molding, and could be corrected by mold rework. However, the annealing cycle is the same as the conditioning required prior to installation on the XM774 105-mm projectile per Dwg. 9329514, and successful installation has been demonstrated.

Dimensional inspection was performed using an optical comparator at 10:1 magnificaion and the transparency shown in Figure 6, page 28.

A total of 30 parts were rejected after visual examination - 3 for machining problems and 27 for inclusions or inside surface blisters. X-ray inspection of 15 parts selected at random showed a total of 4 with small internal voids, and the x-ray negatives were forwarded with the shipment for correlation with tensile/elongation test results. It appears that a complete elimination of voids will require mold modification - possibly the installation of a hot sprue bushing to increase the freeze time in the nylon flow path.

Obturators from this shipment were inspected at ARRADCOM for physical properties per QEP-TR-316 with the results shown in Table 15, page 29.

Installation

Installation of molded VFM2083 obturators onto M735, 105-mm projectiles per Dwg. PA-C12-B, Figure 7, page 30 was performed successfully by ARRADCOM both in house and at Flinchbaugh Products, Inc.,) Wharton, New Jersey. As described in Dwg. Note 3A and B, the obturator was conditioned to 240°F and expanded to bourrellet diameter by being forced over a tapered ramp positioned in contact with the aft end of the projectile. Conditioning time at 240°F and the rate of expansion (time on the tapered ramp) were the variables controlled to meet the drawing torque requirements. Given a conditioning time sufficient to bring the mass of the obturator to an even temperature (45 minutes - approximately), the slower the rate of expansion, the looser the fit. As noted previously, molded obturators with diameters .010 under drawing tolerance were installed meeting the requirements for torque and dimension after installation. It is probable that, given the correct wall thickness and OD contour, a range of diameters outside the drawing tolerance band can be accommodated by control of the installation process.

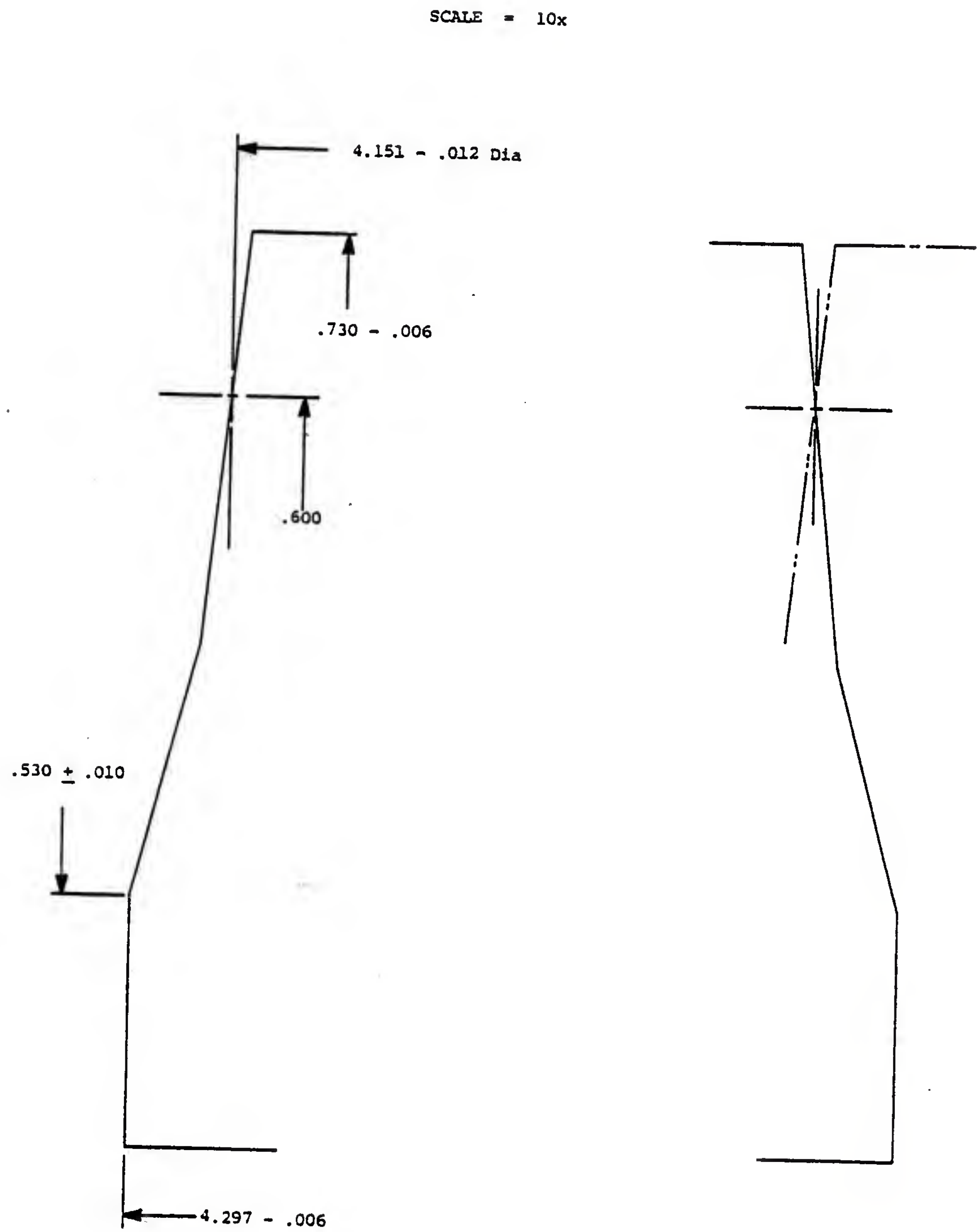


Figure 6. Optical comparator inspection transparency

Table 15. Physical property testing per QEP-TR-316 results reported by ARRADCOM - molding run of 2/16 - 17/82

A. Tensile Elongation at -35°F - Method 4.5.1

Samples (No. Tested)	Ultimate Load (lbs.)	Elongation (inches)
Average (3)	6882	0.48
Std. Deviation	410	0.14
Average (3)*	6133	0.33
Std. Deviation	737	0.04

B. Tensile Elongation at 73°F - Method 4.5.1

Samples (No. Tested)	Ultimate Load (lbs.)	Elongation (inches)
Average (6)	5138	0.82
Std. Deviation	32	0.05
Average (4)*	5146*	0.674*
Std. Deviation	64	0.19

C. Tensile Elongation at +140°F - Method 4.5.1

Samples (No. Tested)	Ultimate Load (lbs.)	Elongation (inches)
Average (4)	3655	3.26
Std. Deviation	26	0.83
Average (2)*	3740*	1.48*
Std. Deviation	35	0.03

D. Rockwell Hardness R Scale - Method 4.5.2

Average value (3) 116

E. Specific Gravity - Method 4.5.3

Average value 1.14

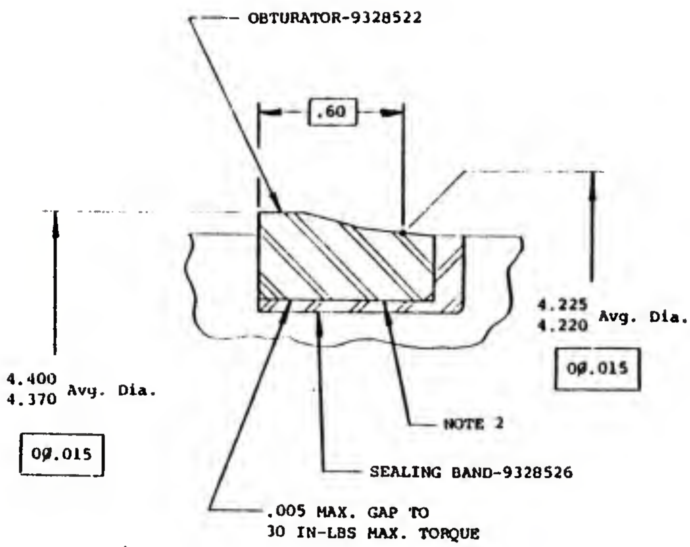
F. Moisture Content - Percent - Method 4.5.4

Average value 0.16

G. Water Adsorption - Percent - Method 4.5.4

Average value (5) 0.58

*Values reported for parts with known voids from x-ray inspection. Parts with voids - approximately 16% of the shipment - were used for (3) of the (30) projectiles fired at JPG. Data reported in Table 16.



NOTES:

1. Band Sealing Assembly:
   A. Clean Obturator Area of Sabot with Degreasing Solvent and Force Air Dry.
   B. Heat Band, Sealing 9328526 to 200°F - 10°F for 10 to 120 Minutes. Do not stack in oven or while hot.
   C. Immediately Push Band, Sealing over Aft End of Assembly and Snap in Place on Sabot.
   D. Allow Band, Sealing to Return to Room Temperature.

2. Preparation for Obturator Assembly:
   A. Clean Band, Sealing, 9328526, with Solvent Cleaner and Force Air Dry. WARNING: Do not use Trichloroethane as Cleaning Agent.
   B. Spray Band, Sealing, 9328526, With Fluorocarbon Dry Lubricant, MIL-L-60326.

3. Obturator Assembly:
   A. Heat Obturator, 9328522, to 240°±10°F for 30 to 120 Minutes in Oven.
   B. Push Obturator Over Aft End of Assembly and Snap in Place on Sabot.
   C. Allow Obturator to Return to Room Temperature.

REFERENCE:

AARADCOM DWG. 9329514 NOTES 3 & 4
AARADCOM DWG. 9329515 NOTE 8

Figure 7. Sealing band and obturator assembly procedure and dimensions

Firing Trials

Thirty molded VFM 2083A obturators from the run of 2/16 - 17/82 were assembled to M735 projectiles by ARRADCOM and fired at Jefferson Proving Ground on 5/26-27/82. These projectiles were conditioned to the temperatures indicated and fired against standard M735 projectiles as controls. Comparative uncorrected muzzle velocity data is presented in Table 16 below.

Table 16. Uncorrected muzzle velocity - molded versus standard obturators on M735 projectiles

TEST DATA

70°F ROUND	UNCORRECTED MUZZLE VEL FPS	-53°F ROUND	UNCORRECTED MUZZLE VEL FPS	145°F ROUND	UNCORRECTED MUZZLE VEL FPS
SPOTTER	4,940	SPOTTER	4,674	SPOTTER	5,166
SPOTTER	4,938	SPOTTER	4,668	SPOTTER	5,195
SPOTTER	4,944	SPOTTER	4,679	SPOTTER	5,176
SPOTTER	4,938	SPOTTER	4,673	SPOTTER	5,185
SPOTTER	4,935	SPOTTER	4,675	SPOTTER	5,180
CONTROL	4,956	CONTROL	4,685	305	5,200
160	4,960	165	4,685	362	5,206
CONTROL	4,942	CONTROL	4,689	330	5,210
279	4,952	157	4,696	170	5,190
CONTROL	4,947	CONTROL	4,695	*154	5,184
213	4,958	167	4,676	136	5,205
CONTROL	4,945	CONTROL	4,682	294	5,198
315	4,971	285	4,676	158	5,203
CONTROL	4,949	CONTROL	4,681	363	5,196
308	4,953	318	4,693	166	5,199
CONTROL	4,949	CONTROL	4,687		
58	4,957	268	4,683		
CONTROL	4,953	CONTROL	4,682		
169	4,958	159	4,680		
CONTROL	4,949	CONTROL	4,688		
*142	4,955	162	4,672		
CONTROL	4,952	CONTROL	4,682		
309	4,966	252	4,674		
CONTROL	4,945	CONTROL	4,691		
*53	4,961	307	4,679		

*Obturators with known voids.

CONCLUSIONS

VFM2083 A obturators have been injection molded from Nylon 6/6 (Zytel 101L) demonstrating the viability of a commercially available material and a non-proprietary process.

Molded obturators meet all the physical property requirements specified by drawing with the exception of water absorption, % max.

Molded obturators have been installed on M735 projectiles using standard equipment with minor modifications in operating conditions and have met drawing requirements for torque and dimensions.

Molded obturators have demonstrated performance equivalent to cast nylon obturators in firing trials over a temperature range of -50°F to +145°F.

RECOMMENDATIONS

A mold modification program designed to eliminate the void problem in molded parts is recommended. Gating into the thick end, and the use of a hot sprue bushing and/or a hot runner system offer possible solutions to the problem.

If the void problem can be eliminated, higher mold temperature cycle parameter should be investigated. Later work under Contract DAAK10-82-C-0051 suggests that sufficient annealing can be obtained in a 180°F mold to eliminate the need for (and the cost of) a post molding annealing cycle.

Obturators should be evaluated for both physical properties and ballistic results at a moisture content of 2.5 percent. The 2.5 percent level is a good approximation of long term uncontrolled field storage conditions.

Alternate nylon types should be evaluated - particularly those such as 612 and 12 which do not pick up as much moisture as 6/6 and have less change in physical properties with moisture. Long term 50% RH moisture content levels are:

Nylon 6/6	2.5 percent
Nylon 612	1.3 percent
Nylon 12	0.9 percent

APPENDIX

SECTION A

CERTIFICATION AND TEST DATA

FOR ZYTEL 101L LOT 53-KN-04

CERTIFICATION
DATE: 3 February 1982

DU PONT COMPANY
POLYMER PRODUCTS DEPARTMENT

CUSTOMER SPECIFICATIONS
PRODUCT CERTIFICATION TESTS

PRODUCT: Zytel® 101L NC-10 SPECIFICATION: MIL-M-20693B TYPE I

Tests	Procedure	Limits	Results
Batch Acceptance Inspection		LOT NO:	53 KN 04
Melt Point	ASTM D-789	250-260°C	260
Specific Gravity	ASTM D-792 or D-1505	1.13-1.15	1.13
Relative Viscosity	ASTM D-789	49 Min.	52
Moisture Content	ASTM D-789	0.28% Max.	0.20
Periodic Batch-Check Inspection		LAST TEST DATE:	March 1981
Deformation Under Load @ 2000 psi	ASTM D-621	1.4% Max.	1.4
Stiffness	ASTM D-747	200,000 psi Min.	296,000
Tensile Strength	ASTM D-638	11,000 psi Min.	11,100
Elongation	ASTM D-638	50% Min.	59
Izod Impact Strength Notched	ASTM D-256	0.80 ft.lb./in. Min.	1.1
Heat Distortion Temp	ASTM D-648		
@ 66 psi		182°C Min.	247
@ 264 psi		66°C Min.	76
Water Absorption	ASTM D-570	1.5% Max.	1.4

APPENDIX

SECTION B

PHOTOGRAPHS OF EQUIPMENT USED

Figure B-1. Single cavity mold mounted in press

Figure B-2. Molded obturator at ejection

Figure B-3. Box used for slow cool and anneal

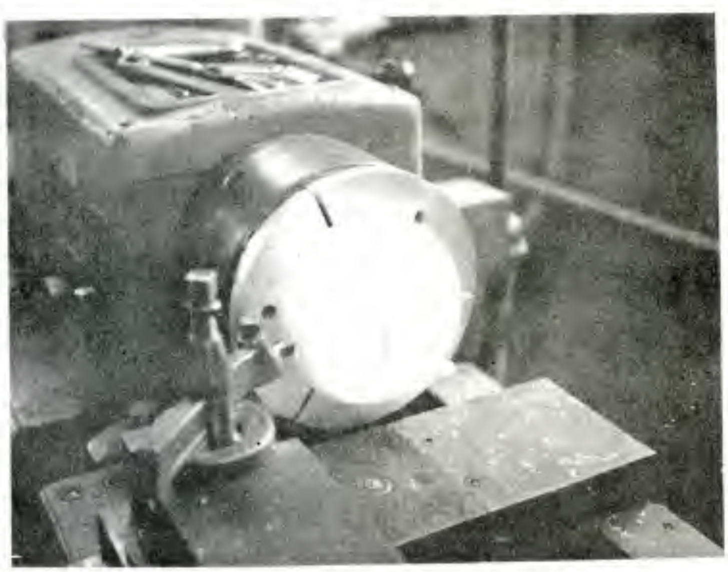


Figure B-4. Removal of diaphragm gate and sprue machine to length and chamfer ID

APPENDIX

SECTION C

MOLDING CYCLE DATA SHEETS

MOLDING CYCLE DATA BUHLER 175

Project No. 6078.3

PART: VFM 2083A Obturator

DATE: 4/7/81

MATERIAL: See Below

CONDITIONING: New Bags as Received

Cycle Data	Nylon 6/6 Zytel 101L	Nylon 6 Allied 8202	Nylon 6 Allied 8253
Temperatures: ^{o}F			
Rear Zone	530	420	430
Center Zone	515	430	440
Front Zone	520	450	460
Melt	530	445	465
Mold Cavity	150	100	100
Mold Core	150	100	100
Pressures: PSI			
Injection - Material	7250	7250	7250
Hold - Material	7250	7250	7250
Time - Seconds:			
Injection	30	30	30
Hold	10	10	10
Closed	60	60	60
General:			
Screw Dia.	45	-	-
Compression Ratio	2.9:1	-	-
Screw RPM	Medium	-	-
Speed Set 0-18	Slow	-	-
Spure "O"	1/8	-	-

MOLDING CYCLE DATA BELOIT 325 RS-6

Project No. 6078.3

PART: VFM 2083A Obturator

DATE: 6/5/81

MATERIAL: Zytel 101L

CONDITIONING: New Bags as Received

Cycle Data	B	C	D	E
Temperatures: ^{o}F				
Rear Zone	540	-	-	-
Center Zone	540	-	-	-
Front Zone	540	-	-	-
Nozzle	550	-	-	-
Melt	540	-	-	-
Mold Cavity	150	-	-	200
Mold Core	150	-	-	200
Pressures: PSI				
Injection - Gage	800	-	1000	-
Hold - Gage	600	-	800	-
Clamp - Gage	1500	-	-	-
Back - Gage	75	-	-	-
Cavity - Chart	10400	-	13000	-
Time - Seconds:				
Injection	15	30	-	-
Hold	45	60	-	-
Closed	60	60	-	-
Slow Open	1/2	-	-	-
Slow Close	1/2	-	-	-
Cycle Over All	105	120	-	-
General:				
Screw Dia.	1 3/4	-	-	-
Compression Ratio	3.5:1	-	-	-
Screw RPM	50	-	-	-
Stroke Set	3 1/2	-	-	-
Cushion	1/2	-	-	-
Speed Set 0-18	2	-	-	-
Inject-Normal-Fast	N	-	-	-
Tip Dia.	7/32	-	-	-
Sprue "O"	9/32	-	-	-

MOLDING CYCLE DATA BELOIT 325 RS-6

Project No. 6078.3

PART: VFM 2038A Obturator - Initial Quality Sample

DATE: 6/23/81

MATERIAL: Zytel 101L Lot 53DN04

CONDITIONING: 18 hrs. 170°F Dry Air

Cycle Data

Temperatures:	°F
Rear Zone	540
Center Zone	560
Front Zone	560
Nozzle	600
Melt	560
Mold Cavity	150
Mold Core	150

Pressures:	
Injection - Gage	1000
Hold - Gage	800
Clamp - Gage	1500
Back - Gage	75
Cavity - Chart	13000

Times - Seconds:	
Injection	30
Hold	60
Closed	60
Slow Open	1/2
Slow Close	1/2
Screw Recovery	20
Cycle Over All	120

General:	
Screw Dia.	1 3/4
Compression Ratio	3.5:1
Screw RPM	60
Stroke Set	3 1/2
Cushion	1/2
Speed Set 0-18	2
Inject-Normal-Fast	N
Tip Dia.	7/32
Sprue "O"	9/32

MOLDING CYCLE DATA BELOIT 325 RS-6

Project No. 6078.3

PART: VFM 2083A Obturator

DATE: 8/13/81

MATERIAL: Zytel 101L Lot 63FN04

CONDITIONING: New Bags as Received

Cycle Data	6K	8K	10K
Temperatures: °F			
Rear Zone	540	540	540
Center Zone	540	540	540
Front Zone	550	550	550
Nozzle	550	570	570
Melt	540	540	540
Mold Cavity	150	150	150
Mold Core	150	150	150
Pressures:			
Injection - Gage	510	670	860
Hold - Gage	400	400	400
Clamp - Gage	1550	1550	1550
Back - Gage	75	75	75
Cavity - Chart	6000	8000	10000
Times - Seconds:			
Injection	59	59	59
Hold	60	60	60
Closed	60	60	60
Slow Open	1/2	1/2	1/2
Slow Close	1/2	1/2	1/2
Screw Recovery	25	26	27
Cycle Over All	120	120	120
General:			
Screw Dia.	1 3/4	-	-
Compression Ratio	3.5:1	-	-
Screw RPM	50	-	-
Stroke Set	3 1/2	-	-
Cushion	1/2	-	-
Speed Set 0-18	2	-	-
Inject-Normal-Fast	N	-	-
Tip Dia.	7/32	-	-
Sprue "O"	9/32	-	-

MOLDING CYCLE DATA BELOIT 325 RS-6
Project 6078.3

PART: VFM 2038A Obturators
DATE: 8/14/81-8/17/81
MATERIAL: Zytel 101L Lot 63FN04
CONDITIONING: Stored in Glass - N_2 Purge

Cycle Data	150°F Mold #'s 1-48	195°F Mold #'s 49-68
Temperatures: °F		
Rear Zone	540	540
Center Zone	540	540
Front Zone	550	550
Nozzle	580	580
Melt	540	540
Mold Cavity	150	195
Mold Core	150	195
Pressures:		
Injection - Gage	520	520
Hold - Gage	400	400
Clamp - Gage	1550	1550
Back - Gage	75	75
Cavity - Chart	6000	6000
Times - Seconds:		
Injection	59	59
Hold	60	60
Closed	60	60
Slow Open	1/2	1/2
Slow Close	1/2	1/2
Screw Recovery	26	25
Cycle Over All	120	120
General:		
Screw Dia.	1 3/4	-
Compression Ratio	3.5:1	-
Screw RPM	50	-
Stroke Set	3 1/2	-
Cushion	1/2	-
Speed Set 0-18	2	-
Inject-Normal-Fast	N	-
Tip Dia.	7/32	-
Sprue "O"	9/32	-

MOLDING CYCLE DATA BELOIT 325-RS-6

Project No. 6078.3

PART: Obturator VFM 2083A

DATE: 9/17/81

MATERIAL: 101L Lot 53DN04

CONDITIONING: A/R Glass - N_2

Cycle Data	"A"	"B"	"C"	"D"
Temperatures: ^oF				
Feed Zone	CW			
Rear Zone	540			
Center Zone	540			
Front Zone	550			
Nozzle	600			
Melt	550			
Mold Cavity	150	150	150	100
Mold Core	150	150	100	100
Sprue Plate	150	200	200	200
Pressures:				
Injection	520			
Hold	400			
Clamp	1500			
Back	75			
Cavity	6000			
Times:				
Injection	59			
Hold	60			
Closed	60			
Slow Open	1/2			
Slow Close	1/2			
Screw Recovery	26±1			
Cycle Over All	120			
General:				
Screw Dia.	1 3/4			
Compression Ratio	3.5:1			
Screw RPM	50			
Stroke Set	3 1/2			
Cushion	1/2			
Speed Set 0-18	2			
Inject-Normal-Fast	N			
Tip Dia.	7/32			
Sprue "O"	9/32			

MOLDING CYCLE DATA BELOIT 325 RS-6

Project No. 6078.3

PART:	Obturator VFM 2083A
DATE:	2/16-17/82
MATERIAL:	Zytel 101L Lot 53RN04
CONDITIONING:	New Bags as Received

Cycle Data	1-330
Temperatures: $^{\circ}F$	
Rear Zone	540
Center Zone	540
Front Zone	550
Nozzle	600
Melt	548
Mold Cavity	150
Mold Core	150
Pressures: PSI	
Injection - Gage	520
Hold - Gage	400
Clamp - Gage	1500
Back - Gage	75
Cavity - Chart	6000
Times - Seconds:	
Injection	59
Hold	60
Closed	60
Slow Open	1/2
Slow Close	1/2
Screw Recovery	26
Cycle Over All	120
General:	
Screw Dia.	1 3/4
Compression Ratio	3.5:1
Screw RPM	50
Stroke Set	3 1/2
Cushion	1/2
Speed Set 0-18	2
Inject-Normal-Fast	N
Tip Dia.	7/32
Sprue "O"	9/32

APPENDIX

SECTION D

TYPICAL CAVITY PRESSURE CURVES

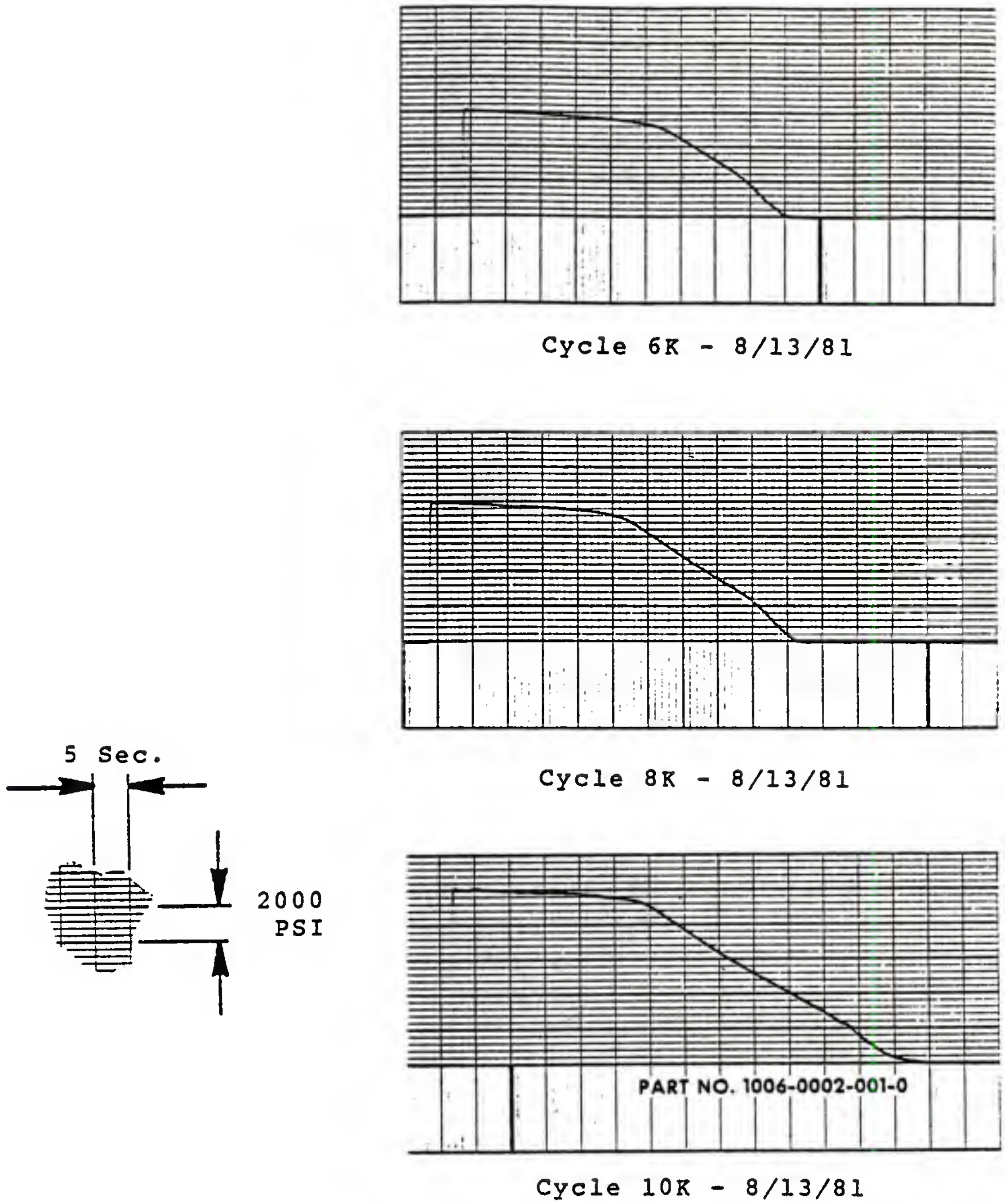
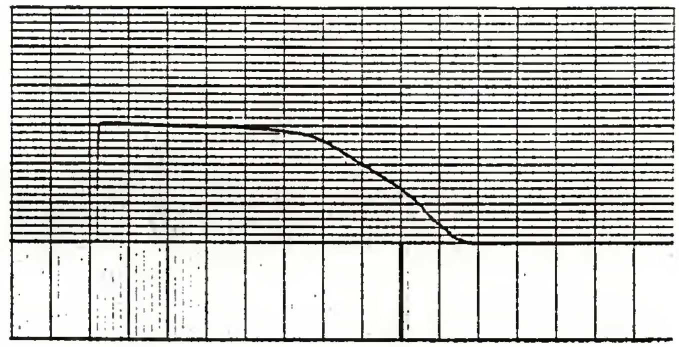
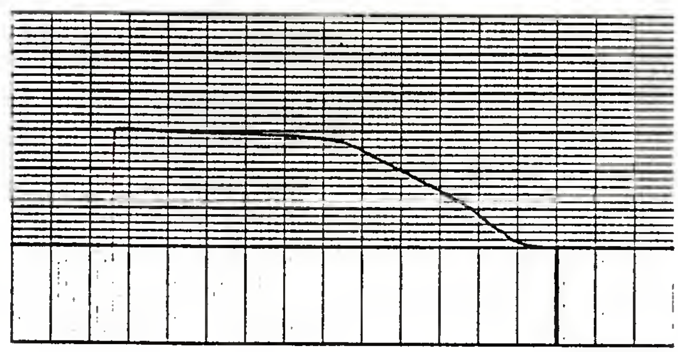


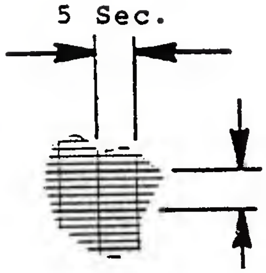
Figure D-1. Cavity pressure versus time for typical initial tests

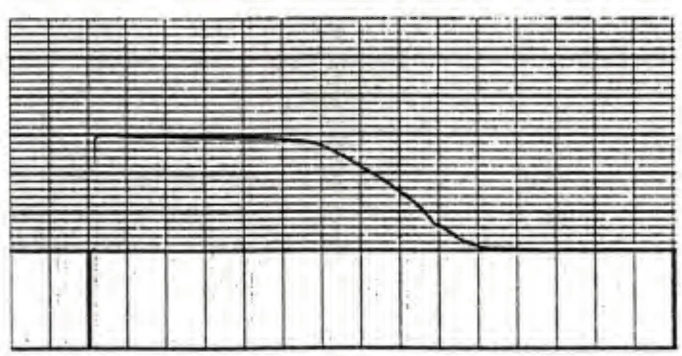


Cycle 6K - 150°F - 8/14/81



Cycle 6K - 195°F - 8/14/81





Final Cycle - 2/16/82

Figure D-2. Cavity pressure versus time for typical additional tests

APPENDIX

SECTION E

ORIGINAL STATEMENT OF WORK AND MODIFICATION P0004

FOR DEVELOPMENT, TESTING, AND DELIVERY OF THE M735 PROJECTILE

I. OBJECTIVE:

The contractor shall devote the required personnel and facilities to evaluate present and alternative materials and manufacturing processes toward accomplishment of a nonproprietary, mass producible, and economic obturator which will function satisfactorily when used on the 105MM M735 Cartridge under all required operational conditions.

II. BACKGROUND:

1. The 105MM, APFSDS Cartridge uses a nylon obturator to seal the high pressure (71,000PSI) propellant gases and provide a controlled spin rate during the gun firing. At present, this obturator is being made from 6/6 nylon which is centrifugally cast. There is only one known manufacturer that successfully uses this technique. In addition, the process used by this manufacturer is proprietary and not available to the commercial public.

2. In order to broaden the production base for nylon obturators, alternate processes and materials for producing acceptable obturators in production quantities are being solicited. The materials and/or the processes used must be nonproprietary and readily available to industry.

3. Similar types of obturators are also used on several other types of ammunition. Therefore, technology developed for the M735 application will also be beneficial to other ammunition items.

III. PROCEDURE:

1. The contractor will evaluate the present material, and possible alternative materials, and select the most economical and mass producible material and manufacturing process for making the required obturators. The process selected shall be compatible with a required production rate of 20,000 units per month on a quantity procurement of 100,000 and shall be nonproprietary in nature. Any material selected other than that specified on drawing No. VFM 2083 shall be approved by the ARRADCOM PCO prior to procurement or fabrication.

2. The contractor will fabricate 50 prototype samples of obturators using the approved material and process. The dimensional and physical properties of the fabricated obturators shall meet the requriements of drawing NO. VFM 2083. The Government will evaluate the 50 prototype samples and notify the Contractor of its approval or disapproval in writing within thirty (30) days after the sample delivery.

3. The contractor will perform the dimensional and physical inspection and tests required in Spec QEP-TR-316. The samples tested shall be in addition to the deliverable quantity.

4. The contractor will demonstrate that the new obturator will assemble to the M735 projectile and meet the requirements of drawing number 9312501 Rev G. The assembly procedure used, including preconditioning temperature, rate of application, and configuration of any assembly fixtures or aids, shall be documented.

5. Following successful evaluation of the prototype samples, the contractor will fabricate and deliver 300 samples of obturators for ballistic evaluation tests. The obturators will be delivered to ARRADCOM in accordance with the delivery schedule. The ballistic evaluation tests will be conducted at a Government proving ground. The obturator must perform successfully when ballistically tested as required in QEP-TR-316.

6. All tooling designed and fabricated under this contract will become the property of the US Government upon completion of the contract.

7. The contractor's efforts under this contract shall result in documentation providing a comprehensive process description for the manufacture of acceptable obturators.

8. The acceptance inspection will be in accordance with QEP-TR-316.

IV. <u>REQUIREMENTS</u>:

1. The Contractor will deliver 50 each, Prototype Obturators within 8 weeks after date of contract award and 300 each of Ballistic Test Sample Obturators within 16 weeks after contract award.

2. The 350 each obturators will be shipped to:

Commander
US Army Armament Research and Development Command
ATTN: DRDAR-LCU-CV
Dover, New Jersey 07801

3. Materials and processes used to fabricate the obturators under this contract shall be nonproprietary and commercially available.

MODIFICATION P00004

The purpose of this modification is to:

a. Increase the deliverable quantity to 300 ea. obturators in accordance with drawing No. VFM 2083, Rev. A.

b. Waive requirement for inspection in accordance with QEP-TR-316, provided that the contractor performs his in-process dimensional inspection and submits data to ARRADCOM when lot is shipped. ARRADCOM will contact QEP-TR-316 testing.

c. The obturators will be delivered to ARRADCOM by 12 March 1982.

d. There will be no change in contract price as a result of this modification.

DISTRIBUTION LIST

Commander
U.S. Army Armament Research
and Development Command
ATTN: DRDAR-LCU-CV (2)
DRDAR-LCA-OP (2)
DRDAR-TSS (5)
Dover, NJ 07801

Administrator
Defense Technical Information Center
ATTN: Accessions Division (12)
Cameron Station
Alexandria, VA 22314

Director
U.S. Army Materiel Systems
Analysis Activity
ATTN: DRXSY-MP
Aberdeen Proving Ground, MD 21005

Commander/Director
Chemical Systems Laboratory
U.S. Army Armament Research
and Development Command
ATTN: DRDAR-CLJ-L
DRDAR-CLB-PA
APG, Edgewood Area, MD 20101

Director
Ballistics Research Laboratory
U.S. Army Armament Research
and Development Command
ATTN: DRDAR-TSB-S
Aberdeen Proving Ground, MD 21005

Chief
Benet Weapons Laboratory, LCWSL
U.S. Army Armament Research
and Development Command
ATTN: DRDAR-LCB-TL
Watervliet, NY 12189

Commander
U.S. Army Armament Materiel
Readiness Command
ATTN: DRSAR-LEP-L
Rock Island, IL 61299

Director
U.S. Army TRADOC Systems
  Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002